

MONITORING WARFIGHTER'S PHYSICAL PERFORMANCE DURING SUSTAINED OPERATIONS USING A FIELD EXPEDIENT JUMPING TEST

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ABSTRACT

A sensitive, reliable, field expedient physical performance test would be a valuable tool for monitoring training progress and experimental interventions. We hypothesized that repetitive unloaded jump tests could be used to monitor physical performance status. Twenty-nine U.S. Marines attending Infantry Officer Course performed 1, 5 and 30 repetition unloaded counter-movement squat jumps (UJ) to assess the efficacy of UJ for monitoring physical performance pre and post an 8-d field exercise composed of near-continuous work, sleep disruption and underfeeding (SUSOPS). Peak jump height and power were highest using 1UJ ($p < 0.05$) and fell 4.9 and 8.9%, respectively after SUSOPS ($p < 0.05$). Jump power fell progressively over 30 UJ (19-20%), but SUSOPS had no affect on rate of fatigue. 5UJ offered no advantages over 1UJ and was inadequate to examine changes in muscle fatiguability. In conclusion, 1UJ was a sensitive, easy to implement, physical performance test for monitoring the impact of military training on warfighter readiness.

1. INTRODUCTION

A warfighter's lethality, mobility, and sustainability can be negatively impacted by physical performance decrements. Sustained operations (SUSOPS), which are characterized by near-continuous physical work and environmental stress, sleep disruption and underfeeding for multiple days, has been shown to compromise physical performance (Chicharro et al., 1998; Friedl, 1995; Johnson et al., 1994; Legg and Patton, 1987; Murphy et al., 1984; Nindl et al., 2002; Nindl et al., 1997) and lower work productivity (Nindl et al., 2000). A simple, reliable, field expedient test that is sensitive to the stress of military training would be of value for assessing warfighter readiness and training effectiveness.

A variety of physical performance tests have been utilized to examine warfighter performance and the impact of experimental interventions, such as diet or operational stress. However, the tests used had a high skill component (e.g., maximal lifting capacity), required specialized equipment (e.g., isokinetic strength), lacked portability (e.g., cycle ergometer), were insensitive (e.g., hand grip strength) or had such large within or between

subject variability that it was insensitive to detect modest changes in physical performance (e.g., distance running). It has been recommended that high intensity performance tests should have a low skill component, be safe, be reproducible, and be field expedient (Friedl, 1995). It was our laboratories opinion that a jumping test would meet these criteria.

Recently, our laboratory examined the effects of short duration (72 hrs) SUSOPS on various measures physical performance (Nindl et al., 2002). At the completion of the 72 hrs of SUSOPS, squat jump work and power declined ~9 and 15%, respectively; indicating that short-term SUSOPS produced decrements in a warfighter's jumping performance. The jump test utilized a loaded (30% back squat 1-RM) 30 continuous repetition counter-movement squat jump test. Our laboratory has now investigated whether an unloaded counter-movement squat jump (UJ) test utilizing 1 (1UJ), or, 5 (5UJ) or 30 (30UJ) would produce similar decrements.

We chose an unloaded squat jump test as it would enhance the field expedience of the test by reducing equipment needs, and improve transportability. We included single jump and repetitive jump tests to identify the best single protocol for monitoring performance. A 1UJ would be the most efficient to employ compared to a multiple UJ because of the greater throughput of test subjects. Jump height has also been reported to decline during long-term SUSOPS (Chicharro et al., 1998; Nindl et al., 1997). However, it provides no information regarding anaerobic power and fatiguability. If pacing doesn't compromise generation of maximal power, multiple jump tests offer the potential to measure both maximal power and fatigueability within a single test. The ideal number of repetitions for UJ test has not been examined.

There were two primary purposes of this study. The first was to determine if UJ tests are capable of detecting decrements in physical performance following 8 days of SUSOPS. The second purpose was to evaluate the utility of multiple repetition unloaded jumps for assessment of maximal power.

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2. METHODS

2.1 Subjects

Twenty-nine U.S. Marines (age, 24 ± 1 years; height, 180 ± 6 cm; BM, 82.5 ± 8.2 kg) attending the Infantry Officer Course volunteered to participate in this investigation after being briefed on the experiment and risks of participation. The appropriate Institutional Review Boards approved the study, and the investigators adhered to AR 70-25 and U.S. Army Research Institute of Environmental Medicine 70-25 on Use of Volunteers in Research.

2.2 Experimental Design

Unloaded counter-movement squat jumps were used to assess physical performance before and after the volunteers participated in the Marine Infantry Officer Course 8 day 'war' exercise designed to develop leadership skills in combat situations and included near-continuous work, sleep disruption (~ 4 h/day) and underfeeding (~ 2300 kcal/day).

2.3 Performance Testing

The Marines were familiarized with the jump maneuver and equipment prior to testing. The UJ tests included a single unloaded jump (1UJ), 5 repetition unloaded jump (5UJ) and 30 repetition unloaded jump (30UJ). For pre and post testing, the order of completion for the jumping protocols was 1UJ, 5UJ and the 30UJ, each separated by 3 minutes standing recovery. For the 5UJ and 30UJ tests, the subjects were told to jump as high as possible on each jump while maintaining a steady-pace until completion of the jumps. The depth of the counter-movement was self selected. The Marines wore shorts, t-shirt, socks and athletic shoes during the tests.

During the jump maneuver, the Marines held a wooden rod against their upper trapezius/posterior deltoid muscles (Figure 1). Body position was recorded from the displacement of the wooden rod relative to a linear position transducer suspended overhead. The cable displacement was measured from the transducer every by 0.005 sec by commercial software (Ballistic Measurement System) (Muncie, IN).

Jump power (JP) was calculated for each jump protocol from jump height (JH) attained and body mass (BM) using validated equations (Harman et al, 1991). For the 30UJ, a fatigue index (FI) was calculated by finding the percent decline between the mean JP of repetitions 1-5 and the mean JP for repetitions 26-30. We have previously documented high test-retest reliability (intra-class correlations 0.89-0.98) for repetitive jump

tests that used this measurement system (Alemany et al., 2004).



Figure 1. Picture A shows the unloaded wooden rod connected to the linear positioning transducer cable. Picture B depicts the counter-movement during the squat jump.

2.4 Body Composition

Body mass was measured using a floor scale (Seca Corp., Columbia, MD) and percent body fat was assessed via dual energy x-ray absorptiometry (DEXA) using manufacturer-supplied algorithms (Total Body Analyses, version 3.6, Lunar Corp., Madison, WI) before and after 8-d of SUSOPS. Lean body mass and fat mass were calculated from BM and percent body fat measures (Friedl et al., 1994). Precision of the instrument is better than 0.5% body fat (Nindl et al., 2002).

Total body water and daily energy expenditure were determined using the doubly labeled water technique. (DeLany et al., 1989). Daily energy intake was calculated from empty food wrappers collected daily.

2.5 Statistics

Student's t-test for dependent samples was used to examine effect of SUSOPS on 30UJ FI as well as body composition. Two-way repeated measures ANOVA (test x time) was used to compare differences in JP and JH between the different tests and impact of SUSOPS. Two-way repeated measures ANOVA (Time x repetition) was used to evaluate effect of SUSOPS and repetition number on 5UJ and 30UJ JH and JP. When a comparison was significant Tukey's HSD post-hoc analysis was used to determine where the significance occurred. Data reported as mean \pm SE with significance set at $p < 0.05$.

3. RESULTS

Mean JP declined ($p < 0.05$) from pre to post SUSOPS for 1UJ, 5UJ and 30UJ (Figure 2). Mean JH declined from pre to post SUSOPS, but was statistically different only for 1UJ and 5UJ (Figure 3). Maximal JH and JH were higher for 1UJ compared to 5UJ or 30UJ independent of SUSOPS (Figure 4). The 30UJ test produced a progressive reduction in JP, but SUSOPS appeared to have no effect on the rate of reduction (Figure 5) and FI was unchanged (Figure 6). During the 5UJ test, there was a loss of JP by the third repetition, but no further JP decline (Figure 7). Mean JP was higher on 5UJ even when compared to first 5 jumps during 30UJ (Figure 8).

Average daily energy expenditure during SUSOPS was 3834 ± 200 Kcal/day and the average daily intake was 1540 ± 300 Kcal/day. Changes in body composition and total body water are reported in Table 1. Body mass, fat mass, and lean body mass declined significantly pre to post SUSOPS. Total body water was not significantly different between pre and post measurements.

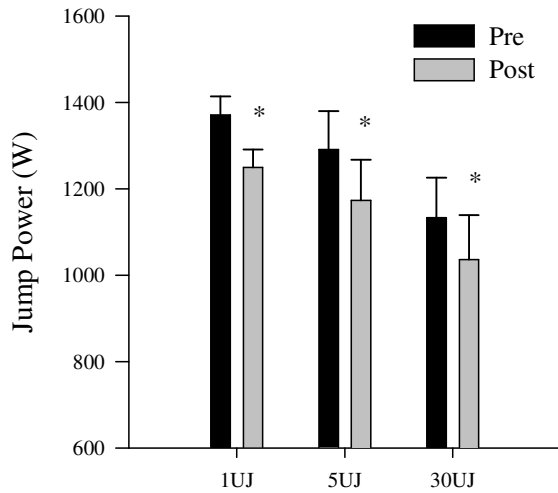


Figure 2. Pre and Post SUSOPS jump power for 1UJ, 5UJ, and 30UJ. Data reported as mean \pm SE. * denotes statistically different between pre and post SUSOPS ($p < 0.05$).

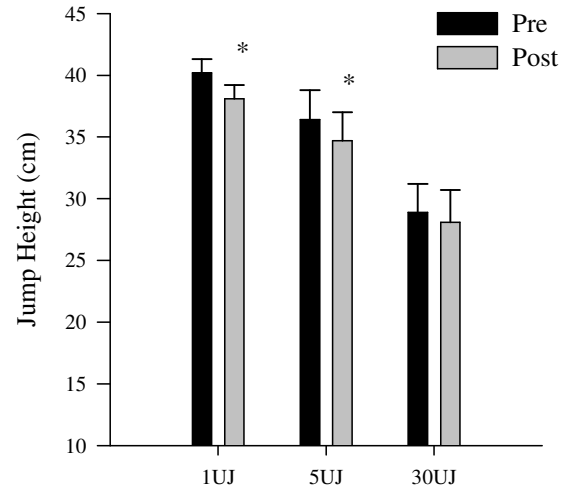


Figure 3. Pre and Post SUSOPS mean jump height for 1UJ, 5UJ, and 30UJ. Data reported as mean \pm SE. * denotes statistically different between pre and post SUSOPS ($p < 0.05$).

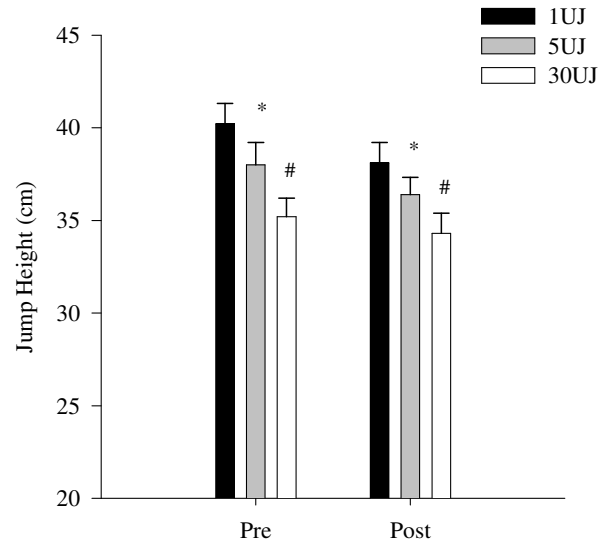


Figure 4. Pre and Post SUSOPS first repetition comparison for maximal jump height among jumping protocols. Data reported as mean \pm SE. * denotes statistically different between 1UJ and first jump of the 5UJ. # indicates significant difference from 1UJ and 5UJ ($p < 0.05$).

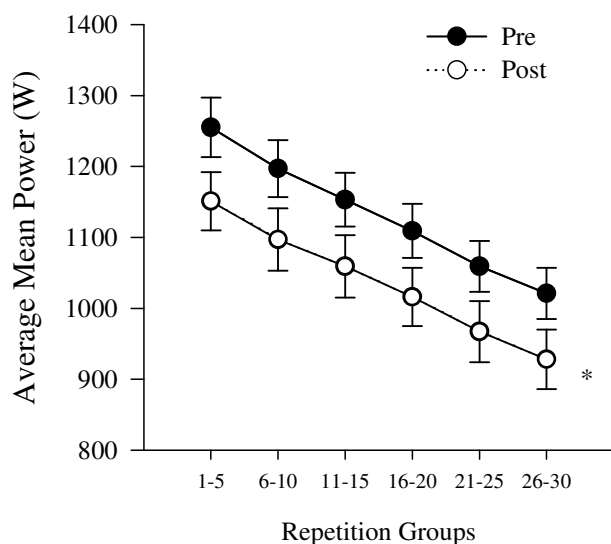


Figure 5. Pre and Post SUSOPS jump power over time for the 30UJ. Repetitions in six groups of five. Data reported as mean \pm SE. * indicates condition effects and a time effect for all data points ($p < 0.05$).

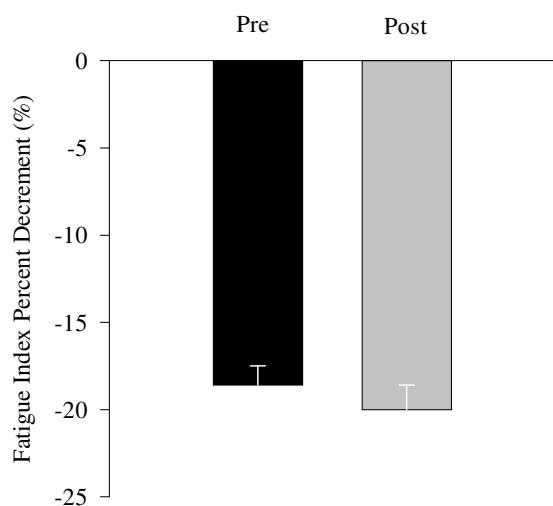


Figure 6. 30UJ fatigue index percent decrement (%) pre and post SUSOPS. Data reported as mean \pm SE ($p < 0.05$).

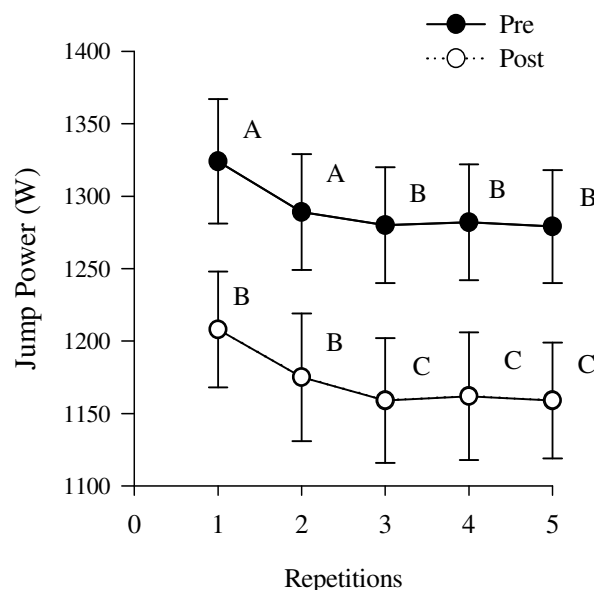


Figure 7. Pre and Post SUSOPS jump power over time for the 5UJ. Data reported as mean \pm SE. Similar letter denote statistically similar. Dissimilar letters denote statistical difference ($p < 0.05$).

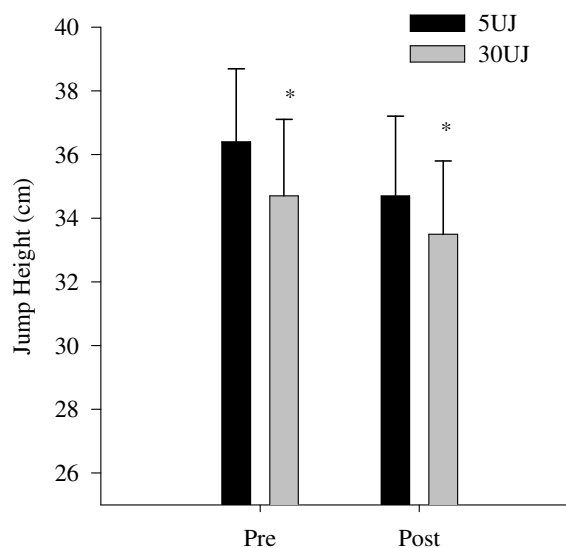


Figure 8. Pre and Post SUSOPS jump height compared between the 5UJ and the first five jumps of the 30UJ. Data reported as mean \pm SE. * denotes statistically different between 5UJ and the first 5 jumps of the 30UJ ($p < 0.05$).

Table 1. Body composition pre to post 8 days of SUSOPS for body mass (BM; kg), Fat mass (FM; kg), lean body mass (LBM; kg), and total body water (TBW; L). * denotes significant difference pre to post SUSOPS ($p < 0.05$). Data reported as mean \pm SE.

| | Pre | Post | % Δ |
|-----|----------------|-----------------|------------|
| BM | 83.1 \pm 1.4 | 79.7 \pm 1.3* | -4.1% |
| FM | 13.3 \pm 0.6 | 11.6 \pm 0.6* | -12.7% |
| LBM | 69.8 \pm 1.2 | 68.2 \pm 1.2* | -2.4% |
| TBW | 46.8 \pm 3.2 | 47.5 \pm 3.2 | 1.5% |

4. CONCLUSION

The purpose of this investigation was to examine the utility of unloaded jump tests to monitor physical performance. Squat jumping was selected because of its simplicity, reliability and field expediency. We utilized several unloaded squat jump tests to evaluate their relative merit for detecting changes in physical performance. An 8-day SUSOPS was chosen as an experimental variable as performance decrements would be anticipated. The primary finding of this investigation was that unloaded jump tests are sufficiently sensitive to detect lower body power decrements associated with military field training.

Jump performance declined over the 8-d SUSOPS. 1UJ JP and JH fell 8.9% and 4.9%, respectively (Figure 2, Figure 3). Similar decrements were also seen using the 5UJ and 30UJ tests. These findings agree with other studies examining the effects of continuous physical activity, sleep deprivation and underfeeding on physical performance (Chicharro et al., 1998; Friedl, 1995; Johnson et al., 1994; Legg and Patton 1987; Murphy et al., 1984; Nindl et al., 2002; Nindl et al., 1997) and suggest that UJ tests be considered when designing methods to assess efficacy of training and experimental interventions.

The highest maximal jump height and jump power were observed on the 1UJ test. We had hypothesized that the highest jump heights might occur on the second or third jump on the 5 UJ test. Work by others had suggested that the rebound from a previous jump can increase force and power during a countermovement jump (Bosco et al., 1982). This was not the case in this study as the highest JH and JP values occurred on the first of the five jumps. Similarly, the 30UJ peak values never attained those obtained on the 1UJ test. These results demonstrate that when maximal power is desired that single repetition test be used.

30UJ jump performance declined pre to post SUSOPS and produced a progressive loss of jump power. However, no difference between the pre (-18.6%)

and post (-20.0%) FI values were observed (Figure 5, Figure 6). These data suggest that the operational stress associated with 8-d of SUSOPS had limited effects on anaerobic power. Alternatively, the 30UJ may have lacked the sensitivity to detect rate of fatigue changes. The unloaded jump test produced a rather modest FI compared to comparable tests with greater muscular overload (Hodges et al., 2003). Whether addition of a minor load to increase rate of fatigue would have produced different results is unknown. This is an area that requires further investigation.

The observation that 30 UJ produced lower maximal JH and JP values than observed during 1UJ test implies that pacing may have affected the FI, in addition to lowering maximal values. The participants were told to jump as high as possible on each jump, but were unable to reproduce the 1UJ maximal jump heights on either the 5UJ or 30UJ tests. The lower jump heights suggests that either there was persistent fatigue over the testing protocols or that the volunteers chose to pace themselves knowing that they had more than one jump to perform before the end of the test. It is unlikely that inadequate recovery was responsible for the inability to reach maximal JH on the 5UJ test as 3 min rest has been recommended for measuring maximal strength (Harman and Pandorf, 2000). Regardless of the cause, the 30UJ test compromised ability to measure maximal JP and was insensitive to any decrement (if it occurred) in muscle fatigability.

The 5UJ produced maximal values that were less than obtained on 1UJ test and included an insufficient number of jumps to produce a progressive fatigue. As such, the 5UJ test doesn't appear the best test to use as basis for evaluating efficacy of training programs or other intervention that might better sustain physical performance. There appeared to be no advantage to using a 5UJ test over a single 1UJ test for measuring lower body power in either a laboratory or field situation.

SUSOPS produced decrements in maximal jump power despite the fact that BM declined significantly during the course. The loss of BM could have masked small decrements in power (Chicharro et al., 1998; Fogelholm et al., 1993) as weight loss independent of muscle strength loss would be expected to increase JH. Whether BM losses resulted in an underestimate of the absolute effects of the SUSOPS on muscle strength and fatigability cannot be discerned from the current study. The fact that JP fell despite BM loss, implies that SUSOPS affected the ability to produce muscular force or convert that force into JH.

There are several explanations for the loss of lower body muscle power after 8-d SUSOPS. One possibility is

that the near-continuous work resulted in accumulation of micro trauma, which can lower neuromuscular efficiency (Fry et al., 1994) and the visco-elastic properties of the skeletal muscle tissue (Viitasalo et al., 1987). Alternatively, an “acute overtraining” state, independent of overt muscular injury may have resulted in the inability to produce muscle maximal muscle force (Friedl, 1995).

Whether food restriction contributed to the power loss is unclear. The underfeeding produced a 4% BM loss as well as lean body mass loss. Filatre et al., 2001 reported that 7-d of rapid weight loss (3.7% BM loss) in competitive Judo athletes resulted in significantly lower jump performance on 7 and 30 sec repetitive unloaded jump tests. However, in contrast to the situation in this study, the majority of BM lost was due to body water loss. Total body water was similar before and after the 8-d SUSOPS. Underfeeding sustained over several weeks and accompanied by substantial lean and total BM loss is accompanied by loss of muscular power (Johnson et al., 1994; Nindl et al., 1997). However, short-term underfeeding has produced mixed effects on anaerobic power (Montain, 2003).

In conclusion, unloaded jump tests are sensitive, easy to implement physical performance tests and can detect reductions in lower body power accompanying military operational stress. It is recommended that they be considered for monitoring effectiveness of training programs and experimental interventions attempting to sustain or improve lower body power. A single unloaded jump is the best single test for assessment of maximal power.

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